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# An analysis of dislocation of the domed Oxford Lateral Unicompartmental Knee Replacement

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component positioning

## **Abstract**

**Background:** The Oxford Unicompartmental Knee Replacement (OUKR) uses a mobile bearing to minimise wear. Bearing dislocation is a problem in the lateral compartment as the ligaments are loose in flexion. A domed tibia component has been introduced to minimise the risk of dislocation, yet they still occur, particularly medially. The aim of this mechanical study was to compare the Domed and Flat tibial components and to identify surgical factors that influence the risk of dislocation.

**Method:** A jig was constructed to assess the amount of vertical distraction of the lateral OUKR for a dislocation to occur. Three methods of dislocation were assessed: Lateral, Medially over the wall and Anteriorly; the study focused on medial dislocation.

**Results:** Significantly ( $p=0.02$ ) greater vertical distraction was required to dislocate the domed bearing with the tibia rather than the flat. For medial dislocation bearing distance from the wall, femoral component external rotation and tibial rotation were associated with significantly more dislocation over the wall. With the optimal technique with the domed tibia the distraction required to dislocate the bearing medially was 6.4mm, whereas with poor technique it was 4.6mm.

**Conclusions:** This study suggests that to minimise the risk of dislocation the domed tibia should be used. The component should be implanted so the bearing is close to the wall, but does not hit it, and in flexion the femoral and tibial component should be neutrally aligned.

## **Introduction**

Unicompartmental Knee Replacement (UKR) is an established treatment for isolated compartmental osteoarthritis [1]. The medial Oxford UKR (OUKR), (Biomet, Swindon, UK), has a well-documented history of clinical success [1]. However, the original Lateral OUKR, (Biomet, Swindon, UK), had an 11% dislocation rate [2]. To address this unacceptably high rate the operative technique was changed and the implant design modified [3]. The new design had a spherically convex domed tibia which more accurately reflects the anatomy of the natural lateral compartment [3]. Full congruity was maintained by having a bi-concave bearing, which increases entrapment.

The introduction of the domed Lateral OUKR, with the associated changes in operative technique has resulted in a substantial decrease in the dislocation rate. In the reported designer series, the cumulative dislocation rate was 1.7% and clinical outcomes good [3]. However, in other series higher dislocation rates have been reported [4].

The aim of this study was to compare the bearing stability with the domed and flat lateral tibia components and to identify surgical factors that influence the risk of dislocation.

## **Method**

A jig was constructed in which the amount of distraction of the lateral compartment could be measured. A replica medium femoral component was constrained above a

size C tibial component. The femoral component could be moved up and down with a screw. The amount of movement was measured with a linear potentiometer (Model PS-C95P, Strainsense, Potterspur, UK) with an accuracy of 0.01mm, using a Powerlab (ADInstruments Ltd, Dunedin, New Zealand) analogue to digital converter (Figure 1). Additionally, the femoral component could be moved within 10° of internal and external rotation. As dislocation commonly occurs in flexion, the anatomical position of components were described assuming the knee was in flexion.

The tibial component was fixed to a micro-rotation stage, (Standa Ltd, Vilnius, Lithuania), that allowed internal and external rotation to the nearest 0.5arcmin and medial/lateral translation of the tibial component to 0.005 mm.

Initially, with a size C flat tibial component in situ, the jig was calibrated. Five sheets of stainless steel with known thicknesses, (2.02 mm, 3.06 mm, 4.01 mm, 5.04 mm, 6.02 mm), were placed on the flat tibial component and the voltage change registered by the linear potentiometer measured. All measurements were taken three times to gain an accurate mean (Figure 2). From these readings a formula to accurately convert voltage change into millimetres was constructed,  $(H = (-2.59 \times V) + 20.60)$ , where H = height of dislocation and V = change in voltage).

Three directions of dislocation were assessed for all bearings: Laterally, Medially over the tibial wall and Anteriorly. Initially, the position of the femur was measured with the femoral component in full contact with the bearing. The femoral component was progressively elevated until the bearing could be dislocated. The difference

between the height of the femur at dislocation and base line was considered to be the vertical distraction required for dislocation.

The 3 mm bearings were too thin to reliably manipulate and gain an accurate measurement. As a result, 3mm bearings, (exactly matching the domed and flat bearings of the lateral OUKR), were fashioned with an anterior “tongue” which allowed the bearing to be manipulated. The experimental procedure was performed a total of three times for each method of dislocation in each position.

A comparison was first performed between the domed tibia and flat tibia bearings. Bearings, (range 3 mm to 8 mm), were tested in 0° of rotation. The femoral component was fixed in a neutral position with all bearings 1mm from the tibial wall.

Using the domed tibia and a 3mm bearing further analysis was carried out. The effect of tibial component rotation on the distraction required to dislocate the bearing was assessed in 5°, 10°, 15° and 20° of internal rotation and 5° and 10° of external rotation. The effect on bearing position relative to the tibial wall was assessed.

Distances of 0 to 8mm, (in increments of 1mm), from the medial tibial wall were tested with the femoral component in a neutral position and the tibial component in 0 degrees of rotation. Finally, with the tibial component fixed in 0 degrees of rotation and with bearings 1mm from the tibial wall the orientation of the femoral component was altered from 10° of valgus, (external rotation relative to the tibial component), to 10° of varus, (relative internal rotation), in 5° increments. Using the calibration data the voltage levels at baseline and dislocation were converted into the distraction height necessary for dislocation.

Statistical analysis was performed using SPSS for Windows v 18.0 (SPSS Inc., Chicago, Illinois). Analysis of the data illustrated that it was not normally distributed. Therefore, analysis was performed using the Mann-Witney U test or the Kruskal-Wallis test. Intra-observer and Inter-observer variability was assessed with the Kappa statistical test for reliability by dislocating the 3mm bearing laterally with the bearing in 0° of rotation and 1 mm from the wall with the femoral component in neutral position 10 times. Significance was set as  $p < 0.05$ .

## **Results**

Inter-observer reproducibility was good with  $\kappa = 0.68$  and Intra-observer variability was  $\kappa = 0.76$ .

### **Domed vs Flat Bearings**

Different mechanisms of dislocation were needed for the different devices in different directions to achieve the dislocation with minimal distraction. For the flat tibia, dislocation was achieved in each direction by translating the bearing in that direction and rotating the bearing so it maintained fully congruous contact with the femur. With the domed tibia a similar sequence was appropriate for anterior and lateral dislocation. However, medial dislocation onto the wall involved a different sequence of manoeuvres. Firstly, the bearing was translated anterior and extended relative to the femoral component, maintaining full congruence with the femoral component. Secondly, it was internally rotated into valgus until the antero-medial corner was on top of the wall. Finally it was externally rotated and translated medially until the medial edge of the bearing was on top of the wall (Figure 3). Once in this stable position reduction could only be achieved by reversing the steps. Dislocation onto the

wall could also be achieved by a similar series of steps with the bearing going posterior rather than anterior. However, for experimental purposes, medial dislocation onto the wall was always done anteriorly.

For all bearings, (3 to 8 mm thickness), there was a significant difference ( $p=0.02$  for all methods of dislocation) in the femoral component distraction required for bearing dislocation in all three methods of bearing dislocation (Figures 4-6). The mean femoral distraction for dislocating the domed bearing laterally was 5.0 mm (SD: 0.14) versus 2.4 mm (SD: 0.37) for flat bearings, (a 108% increase). Dislocating the domed bearing medially over the wall required a mean distraction of 5.9 mm (SD:0.19) versus 4.1 mm (SD:0.42) for flat bearings, (a 44% increase). When dislocating the domed bearings anteriorly a mean displacement of 7.6 mm (SD: 0.27) was required for domed bearings when compared to 4.5 mm (SD:0.30) for flat bearings, (a 69% increase).

No significant differences were found between the domed bearing thicknesses and femoral distraction required to allow dislocation.

### **Effect of Tibial Rotation**

No significant difference was found when assessing the effect of tibial internal and external rotation on the mean height of femoral distraction required to dislocate the 3mm bearing either laterally or anteriorly ( $p=0.22$  and  $p=0.08$  respectively) (Table 1 and Figure 7).



There was a significant difference ( $p=0.02$ ) when assessing the effect of rotation on dislocating the bearing over the medial wall. The bearing was easiest to dislocate with the tibial component in  $5^\circ$  of internal rotation (mean: 5.5 mm (SD: 0.18)) and most difficult to dislocate in  $10^\circ$  of internal rotation (mean: 6.1 mm (SD: 0.14)).

### **Effect of Bearing Distance from the Tibial Wall**

There was a significant difference ( $p<0.01$ ) in the distance from the medial wall required to dislocate the 3mm domed bearing medially over the wall (Table 2 and Figure 8). To dislocate the bearing medially over the wall the greatest distraction of the femoral component was required when the bearing was against the medial wall, (0 mm away) (mean: 6.4 mm SD: 0.04). The least distraction was required with the bearing 8mm from the wall (mean: 5.0 mm SD: 0.23). However, when the bearing was 2 mm from the wall the displacement required to dislocate the bearing was 5.5 mm (SD: 0.15).

There was no significant difference ( $p=0.05$  and  $p=0.21$ ) in the distraction required to dislocate the 3 mm bearing either laterally or anteriorly depending on the distance of the bearing from the wall.

### **Effect of Femoral Component Internal and External Rotation**

Femoral component angulation had a significant effect ( $p=0.02$  for all) for all method types of dislocation (Table 3 and Figure 9). The least distraction height required to dislocate the 3 mm bearing laterally and anteriorly was with the femoral component in  $10^\circ$  of internal rotation (mean: 4.3 mm, SD: 0.13 and mean: 7.3 mm SD: 0.14,

respectively) whereas to dislocate the bearing medially over the wall the least distraction was found when the component was in 10 degrees of external rotation (mean: 4.7mm SD: 0.17). The optimal rotation to minimise distraction for medial dislocation is neutral.

## **Discussion**

This study has demonstrated that the dislocation of the domed bearing of the Lateral OUKR requires a significantly increased level of femoral distraction for the bearing to dislocate in comparison to the previous flat bearing model. It confirms that the amount of distraction necessary for dislocation depends on the direction of dislocation. Additionally, it demonstrates that the relative position of the femoral and tibial components, and thus surgical technique, influences the risk of dislocation.

For all directions of dislocation the amount of distraction necessary for dislocation is significantly higher with the domed lateral OUKR compared with the standard flat. The amount of distraction increases by 44% for medial dislocation, 108% for lateral and 69% for anterior or posterior. This substantial increase in entrapment suggests that the lower dislocation rate seen clinically with the domed device is a manifestation of an improvement in design. The domed device has other clinical advantages, including more normal kinematics, better range of movement, less pain, less overtightening of the ligaments in high flexion and lower revision rates. Therefore, if a surgeon wishes to use a mobile bearing lateral design it would be advisable to use the domed devices.

Throughout the study the least distraction required to dislocate the bearing was seen when the bearings were dislocated laterally and the greatest was when the bearing dislocated anteriorly or posteriorly. However, clinical studies of both domed and flat UKR have shown that almost all dislocations were medially over the tibial wall [3,5]. This suggests that the lateral soft tissues, which are likely to be tight when the joint is distracted, prevent lateral dislocation. It also suggests that the lateral compartment does not normally distract 7 or 8mm, which is the amount necessary for an anterior dislocation. As medial dislocation requires 6mm distraction, any method that will increase the distraction necessary for a medial dislocation, even by 1mm, is likely to decrease the overall dislocation rate.

As previous studies have demonstrated that when the domed Lateral OUKR dislocates it does so medially over the tibial wall [3,6], we were particularly interested in this method of dislocation. When attempting to identify the easiest method of dislocating the domed bearing medially, it became apparent that dislocation with minimal distraction occurred if the bearing was subluxed anteriorly and twisted so its anterior corner was over the medial wall. It then subluxes so its medial side sits on the wall and becomes trapped between the femoral and tibial components. This method of bearing dislocation is different from that hypothesised previously. This understanding allows us to advise on how surgical technique might prevent bearing dislocation.

To minimise the risk of medial dislocation the bearing needs to be as close as possible to the wall. Clinical observation suggests that in addition to the bearing moving backwards and forwards relative to the tibia, it moves medially near full extension and in high flexion. Therefore to prevent the bearing hitting the wall in these positions

it has to be a few millimeters from the wall in flexion, which is the common angle for dislocation to occur. It is likely that the best way to get the bearing close to the wall in flexion is to do the standard initial vertical cut through the patella tendon and beside the lateral condyle. Then, after inserting the femoral component to do a trial reduction, observe the bearing movement. On the basis of this modify the direction and position of the cut so the bearing just does not hit the wall in full flexion and extension.

For medial dislocation both internal and external angulation of the femoral component reduced the amount of femoral component distraction required for dislocation. Therefore the optimal rotation of the femoral component is neutral. In other words it should be positioned perpendicular to the tibial component, when implanted in flexion.

Rotation of the tibial component relative to the femoral component altered the amount of distraction when dislocating the bearing medially over the wall. The greatest decrease was seen at 5° and 10° of internal rotation when dislocation was initiated by anterior subluxation of the bearing. Had the distraction been initiated with posterior subluxation, the greatest decrease would have been in external rotation. This emphasises the importance of having the tibial and femoral component approximately parallel in flexion. The optimal direction of the tibial cut for bearing tracking is towards the anterior superior iliac spine or roughly parallel to the femoral diaphysis. This suggests that the femoral component drill hole should also be in this direction. The traditional recommendation is that the drill should be directed towards the femoral head. It should, therefore, probably be slightly more valgus than this.

There are clearly limitations to mechanical lab based studies such as this. Replicating dynamic changes in the knee is very difficult, (such as the increased excursion of the lateral femoral condyle relative to the medial femoral condyle [7,8]). Furthermore, they cannot truly duplicate the effect of soft tissue attachments across the joint. As a result, clinical correlation and outcomes are required which make the suggestions of this study a guide.

This mechanical study demonstrates that the domed Lateral OUKR has significantly improved entrapment over its previous flat bearing model. It also demonstrates that to decrease the risk of dislocation of the domed bearing medially over the wall, (which is the most common direction of dislocation), the following should be aimed for:

- a) The bearing should be as close to the wall as possible, but should not be forced against it.
- b) In flexion, the femoral and tibial components should be positioned neutrally relative to each other.

The difference in the amount of distraction for dislocation in the optimal position compared to a suboptimal one is about 1.5 mm which should decrease the dislocation rate. However, a clinical study is necessary to demonstrate if this is the case.

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**Conflict of Interest Statement**

The author or one of more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other nonprofit organisation with which one or more of the authors are associated.

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Table 1: Table describing the mean height of femoral distraction required for a 3mm bearing to be dislocated in different degrees of tibial component rotation for each method of dislocation

Tibial Rotation	Lateral (mm)	Medially - over the wall (mm)	Anteriorly (mm)
10° external rotation	5.2 (SD: 0.02)	5.7 (SD: 0.04)	8.2 (SD: 0.12)
5° external rotation	5.1 (SD: 0.01)	5.9 (SD: 0.09)	8.2 (SD: 0.08)
0° rotation	5.1 (SD: 0.05)	5.9 (SD: 0.18)	8.1 (SD: 0.15)
5° internal rotation	5.2 (SD: 0.02)	5.5 (SD: 0.18)	8.1 (SD: 0.04)
10° internal rotation	5.1 (SD: 0.10)	6.1 (SD: 0.03)	8.0 (SD: 0.05)
15° internal rotation	5.1 (SD: 0.11)	5.5 (SD: 0.15)	8.0 (SD: 0.02)
20° internal rotation	5.1 (SD: 0.06)	5.8 (SD: 0.14)	8.1 (SD: 0.03)



Table 2: Table describing the mean height of femoral distraction required for a 3mm bearing to be dislocated for each method of dislocation when the bearing is different mm from the wall of the tibial bearing

Distance from the wall (mm)	Lateral (mm)	Medially – over the wall (mm)	Anteriorly (mm)
0	5.1 (SD: 0.04)	6.4 (SD: 0.04)	8.2 (SD: 0.14)
1	5.1 (SD: 0.05)	5.9 (SD: 0.18)	8.1 (SD: 0.15)
2	5.0 (SD: 0.07)	5.5 (SD: 0.17)	8.0 (SD: 0.19)
3	5.1 (SD: 0.02)	5.8 (SD: 0.15)	8.0 (SD: 0.20)
4	5.1 (SD: 0.02)	5.4 (SD: 0.07)	8.0 (SD: 0.18)
5	5.0 (SD: 0.02)	5.4 (SD: 0.08)	8.1 (SD: 0.09)
6	5.1 (SD: 0.03)	5.3 (SD: 0.18)	8.1 (SD: 0.08)
7	5.1 (SD: 0.04)	5.4 (SD: 0.11)	8.0 (SD: 0.06)
8	4.9 (SD: 0.14)	5.0 (SD: 0.23)	7.88 (SD: 0.03)

Table 3: Table describing the mean height of femoral distraction required for a 3mm bearing to be dislocated for each method of dislocation with the femoral component in different degrees of angulation

Degrees of femoral component angulation	Lateral (mm)	Medially - over the wall (mm)	Anteriorly (mm)
10° int rot	4.3 (SD: 0.13)	5.2 (0.11)	7.3 (0.14)
5° int rot	4.8 (SD: 0.05)	5.0 (SD: 0.11)	7.6 (SD: 0.17)
0°	5.0 (SD: 0.07)	5.5 (SD: 0.17)	8.0 (SD: 0.19)
5° ext rot	4.7 (SD: 0.04)	5.3 (SD: 0.12)	8.5 (SD: 0.20)
10° ext rot	4.8 (SD: 0.02)	4.6 (SD: 0.17)	8.0 (SD: 0.10)

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(degrees) (negative values represent external rotation and error bars represent standard deviation)

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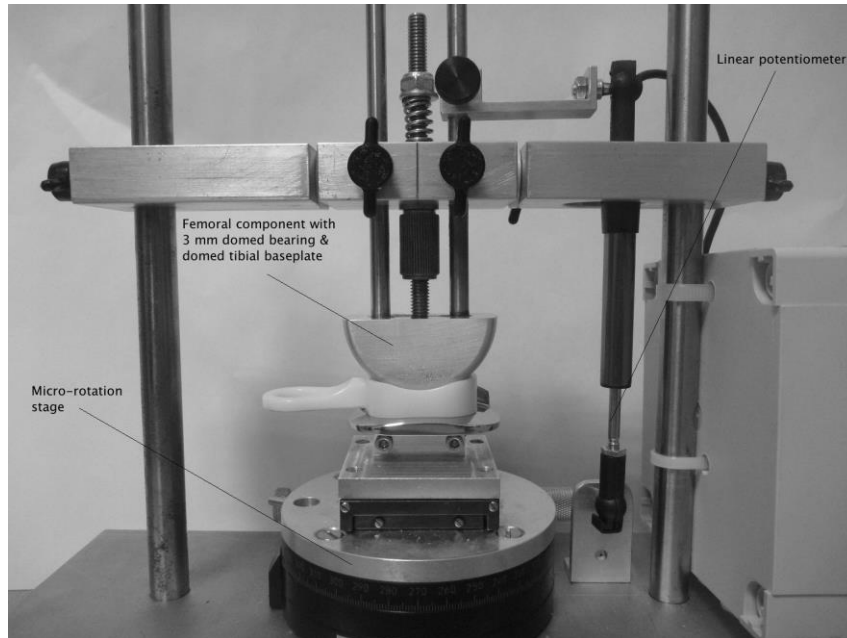


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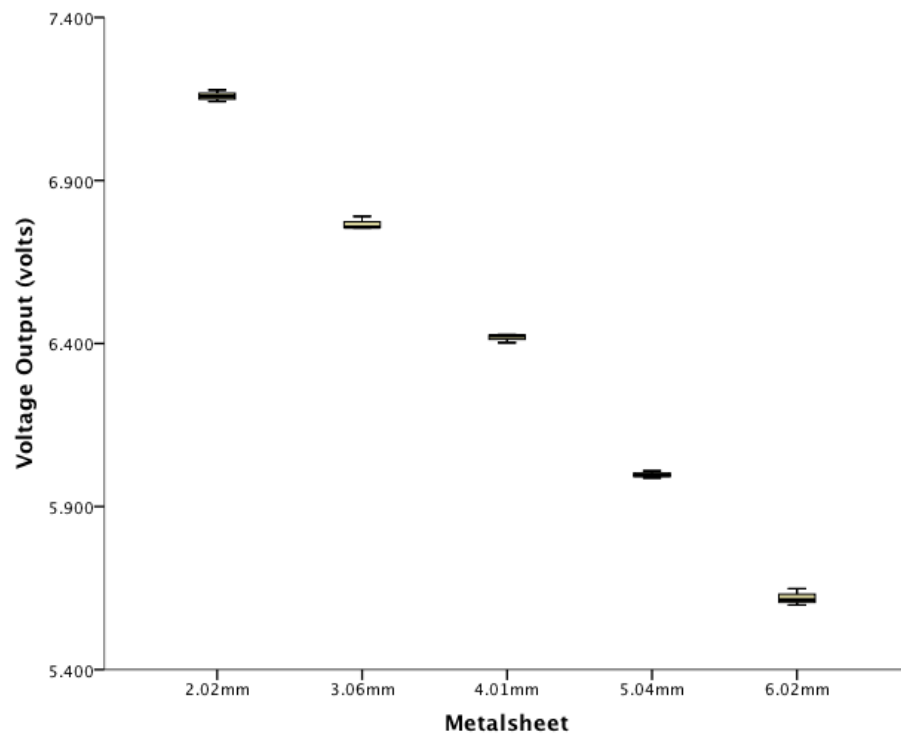


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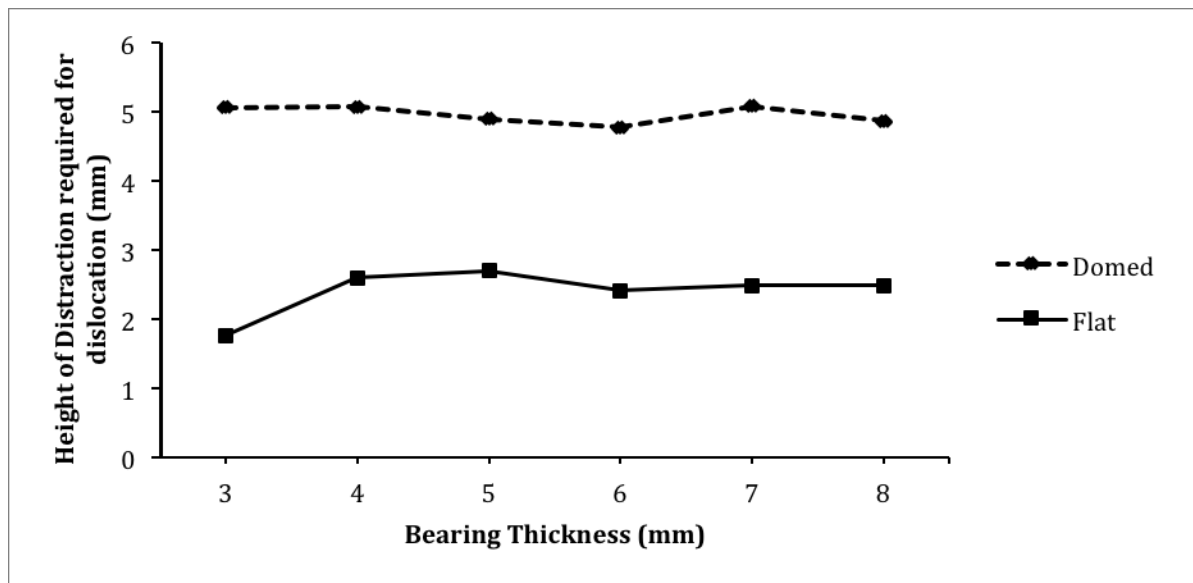




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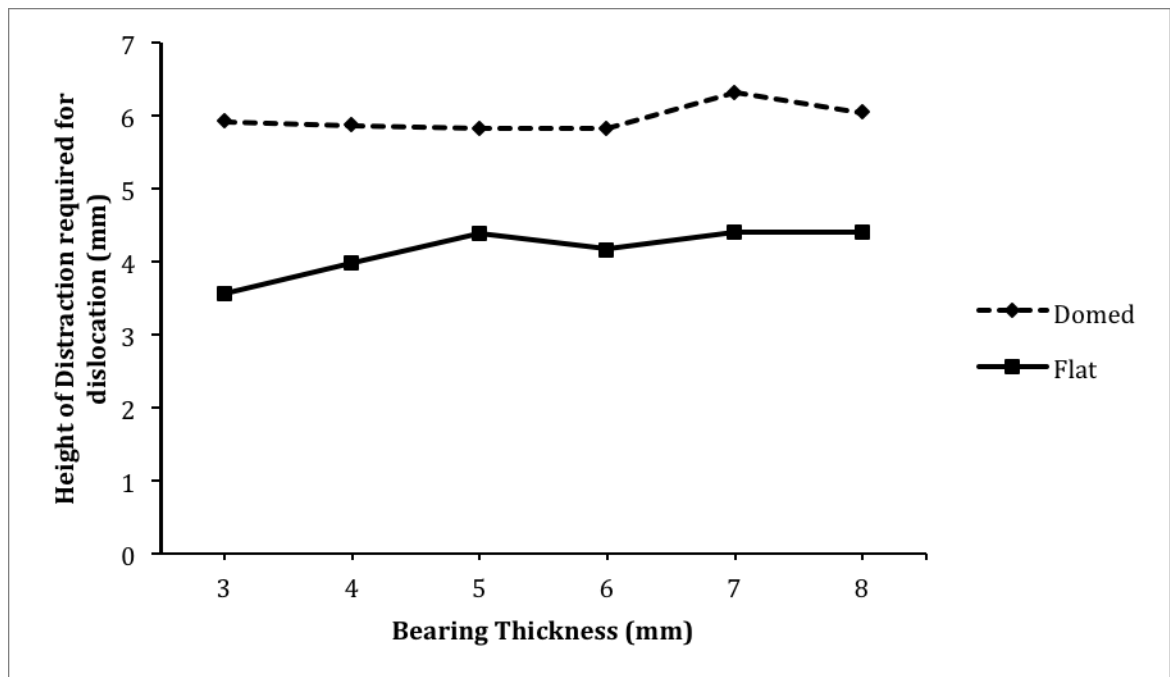


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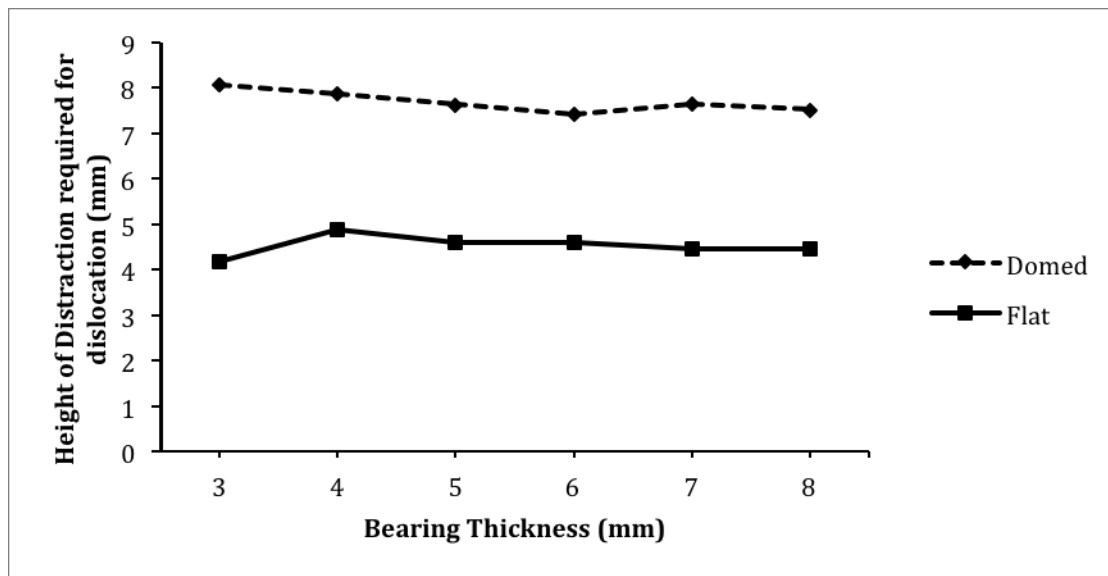


Figure 7: Plot demonstrating the mean height of distraction (mm) necessary for dislocating for the 3 mm domed bearing in differing positions of tibial rotation (negative x-axis values represent degree of external rotation) for all methods of dislocation. (Error bars represent Standard deviation)

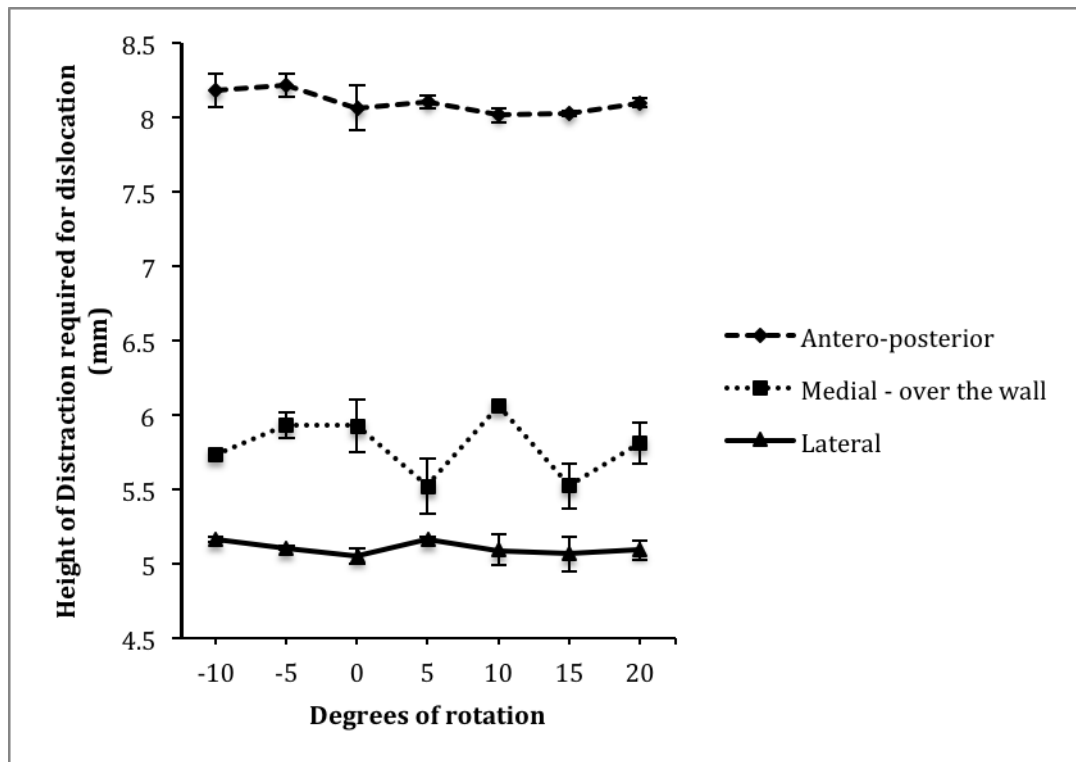


Figure 8: Plot demonstrating the mean height of distraction (mm) necessary for dislocating the 3 mm domed bearing against distance of the bearing from the wall for all three methods of dislocation. (Error bars represent Standard deviation)

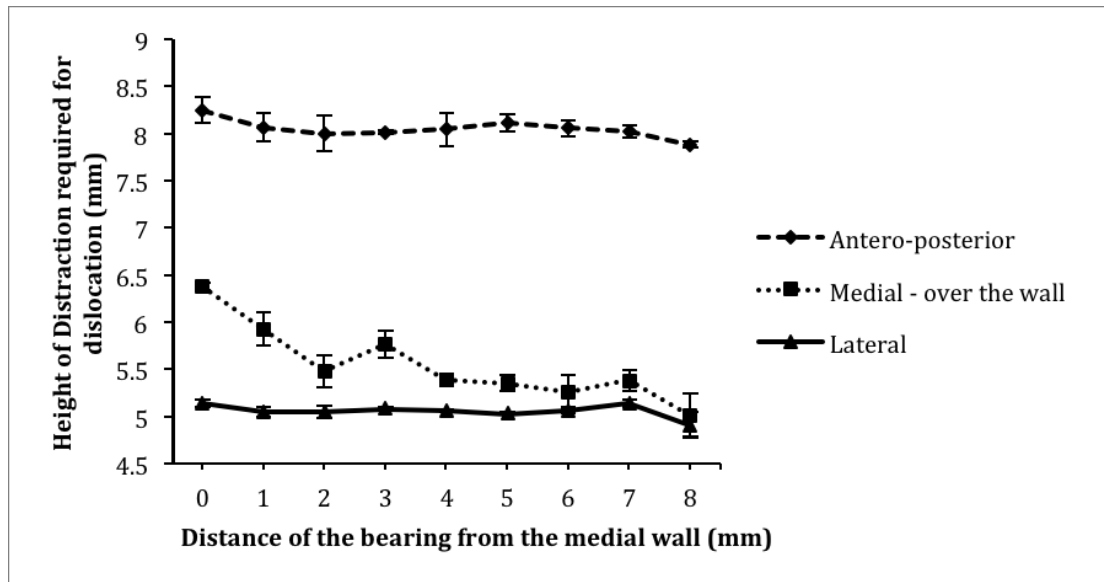


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